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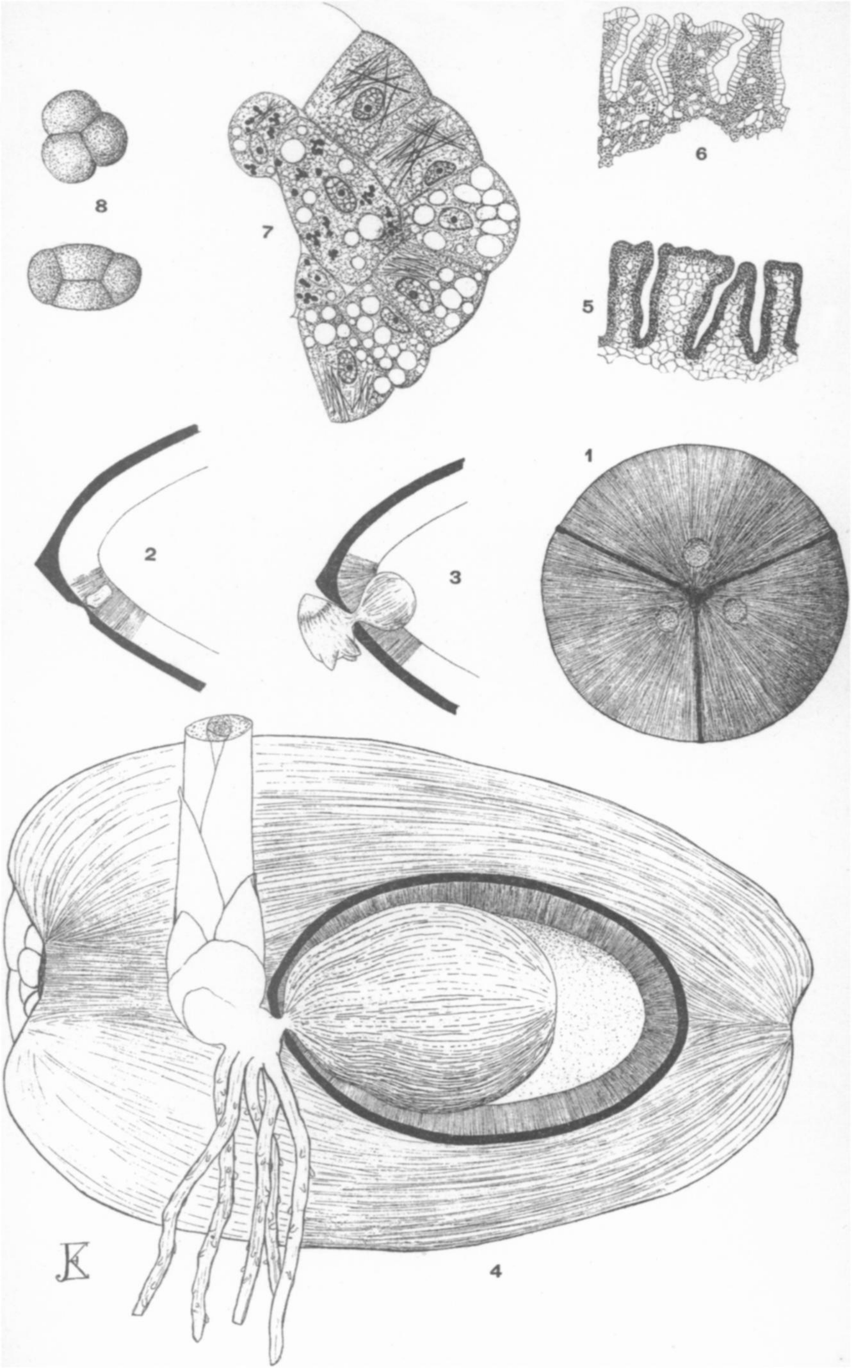

COCOS NUCIFERA.

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Chemical Studies of the Cocoanut with some Notes on the Changes during Germination *

BY J. E. KIRKWOOD AND WILLIAM J. GIES

(WITH PLATE 19)

[From the Laboratory of Physiological Chemistry of Columbia University, and the New York Botanical Garden, New York.]

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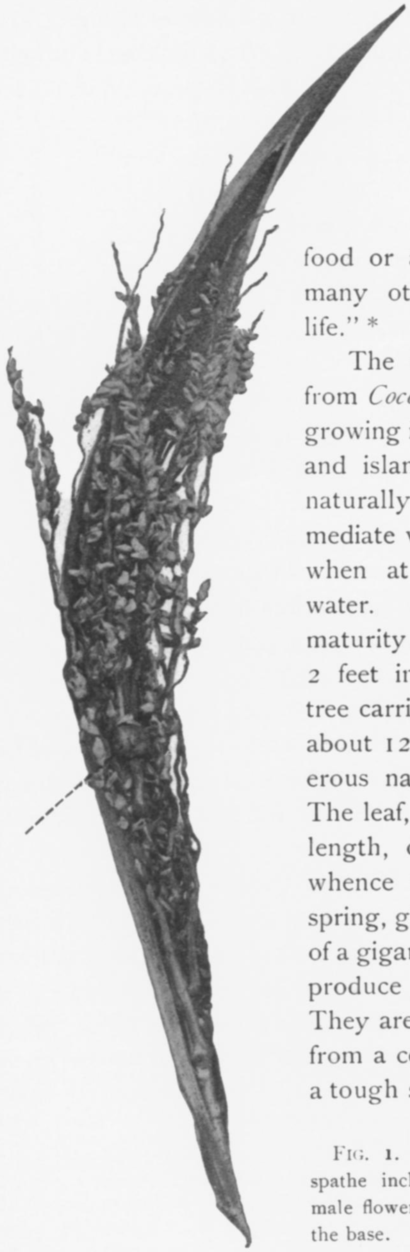
* Preliminary accounts of some of the results of this research were given in the Proceedings of the American Association for the Advancement of Science,— : 275. 1900, and in the Proceedings of the American Physiological Society. 1900 : American Journal of Physiology, 5 : 14. 1901.

The term "coco" appears to be derived from "coc" or "cocus," a local name for the "Indian nut," the fruit of *Cocos nucifera*, given to it on account of a fancied resemblance of the base of the endocarp, with its three circular impressions, to the face of a monkey when it utters a cry having a sound like the word. See *f. 1, pl. 19*. The term "cocoa" should be carefully distinguished from "cacao," the product of *Theobroma cacao*, from "coca" the derivative of *Erythroxylon coca*, from "coco," the coco-kola of commerce, and from "cocco" or "cocoa root" (*Colocasia esculenta*).

[Issued 20 June]

I. INTRODUCTION



"Of the whole class of seeds having the character of luxuries rather than of necessaries, the cocoanut is by far the most important to mankind, whether considered as a delicious and nutritious food or as supplying valuable oil and many other articles useful in social life." *

The common cocoanut is derived from *Cocos nucifera*, a species of palm growing in practically all tropical coasts and islands. The cocoa palm grows naturally on the seashore or in its immediate vicinity and does not bear well when at a great distance from salt water. (See analyses, p. 335.) At maturity it has a cylindrical stem about 2 feet in diameter. At its apex the tree carries a tuft of leaves, which are about 12 feet long. These have numerous narrow, rigid and long leaflets. The leaf, which may attain to 20 feet in length, consists of a strong mid-rib, whence numerous long acute leaflets spring, giving the whole the appearance of a gigantic feather. The flowers which produce the nut are yellowish-white. They are arranged in spikes, branching from a central axis, and inclosed with a tough spathe usually a meter or more

FIG. 1. Inflorescence of the cocoanut showing spathe inclosing the spikes, each with numerous male flowers above and a single female flower near the base. × ⅕. Winton.

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* Smith: Food, 226. 1873.

in length. Their appearance and arrangement is shown in Fig. 1, on the opposite page. The tree grows to a height of about 60–100 feet and usually bears 80–100 nuts arranged on the tree in bunches of 10–20. It continues to bear during two generations of men.

The fruit is subtriangular-ovoid in form, about 12 inches long and 6 inches broad. It is composed of a thick, fibrous "husk" (exocarp) and thin, hard "shell" (endocarp), containing a white fleshy seed, the "meat" (endosperm), with a thin integument (testa). (See *Fig. 3*, p. 324.) The thick husk is remarkably adapted to the preservation of the seed, whilst the nut is tossed about by the waves until it reaches some shore, it may be, far distant from that on which it grew. While immature the nut is without the solid endosperm, but is filled with a milky fluid. As it ripens, however, the endosperm gradually develops and the milky juice diminishes in quantity. The temperature of this juice when fresh is always comparatively low. (See page 349 for further reference to the parts of the nut.)

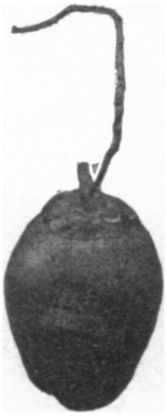

FIG. 2. Half-grown cocoanut fruit with calyx, and axis from which the male flowers have fallen. × $\frac{1}{5}$. Winton.

Figures 1, 2 and 3 are from cuts loaned to us by Dr. A. L. Winton, who used them lately in the account of his very valuable histological study of "The Anatomy of the Fruit of the *Cocos nucifera*."* We are greatly indebted to Dr. Winton for his kind assistance.

The cocoanut forms the chief food of the inhabitants of Ceylon, the South Sea Islands, the coast of Africa and other tropical coasts and islands.† The flesh is not only eaten as it comes from the tree, both ripe and unripe, but it is also prepared and served in various ways. In India the "copra" is much used as an ingredient of curries. It forms an accessory part of the diet, and is found in many of the confections, of civilized man all over the globe.*

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* Winton : American Journal of Science, IV. 12 : 265. 1901.

† The cocoanut is agreeable to the taste of various domestic and other animals, and is eagerly eaten by them. The cocoanut-crab (*Birgus latro*, suborder *Macrura* ; anomalous form, approaching the *Brachyura* and closely related to the hermit crab) feeds almost entirely on the kernel of the cocoanut. Its powerful claws enable it to easily peel off the husk and open the hard shell.

Immoderate use of the fruit, which according to the people of the tropics is highly refrigerant, causes, it is said, rheumatic and other diseases.† The milk is considered an agreeable cooling beverage in the tropics. It has been known for some time that irritation of the mucous membrane of the bladder and urethra is caused by drinking too freely of the cocoanut milk.‡ It is strongly diuretic. Parisi has used the cocoanut therapeutically as an anthelmintic with uniformly satisfactory results.§ He states that the meat of the nut is a powerful *taenicide*, the milk sharing the prop-

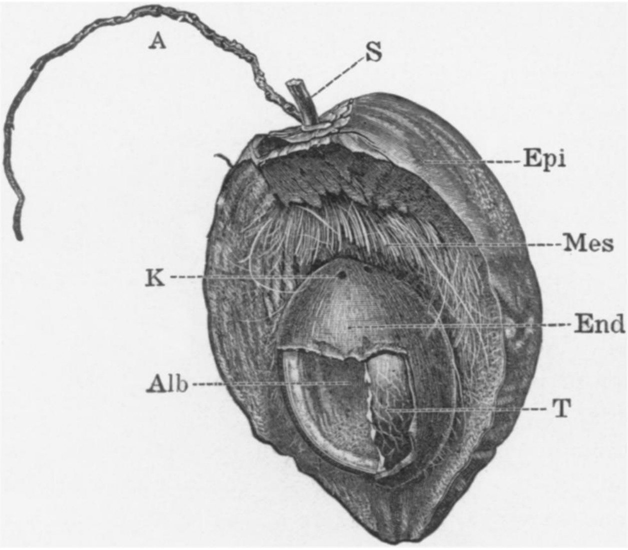

FIG. 3. Ripe cocoanut. *S*, lower part of axis forming the stem; *A*, upper end of axis with scars of male flowers; *Epi*, epicarp; *Mes*, mesocarp with fibers; *End*, endocarp or hard shell; *T*, portion of testa adhering to endosperm; *Alb*, endosperm surrounding cavity of the nut; *K*, germinating eye. × 1/5. Winton.

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* In the Annals of the New York Academy of Science, 13: 490, 1900–1901, the following may be found: "Dr. Gies in answer to a question stated that the food content of the cocoanut is small." This answer is quoted incorrectly. The question referred to the *nitrogenous* food content. It was stated on that occasion that the "content of *proteid* food-stuff is small." See page 340.

† Pavy: A Treatise on Food and Dietetics physiologically and therapeutically considered, 488. 1878.

‡ Curtis: Annals of the New York Academy of Sciences, 13: 490. 1900–1901.

§ See Liebreich: Encyklopaedie der Therapie, 1: 744. 1896.

erty.* The cocoanut has been used as a vermifuge in India for probably forty generations by the beef eaters of that country and is there well known as a means of expelling the flat worm.† The small, green and immature nut is grated fine for medicinal use, and when mixed with the oil of the ripe nut becomes a healing ointment.

The fibrous husk (coir) is widely used for the construction of ropes, brushes, bags, matting, etc. The compact fleshy edible portion (copra), closely lining the hard shell and which is entirely fluid or gelatinous when young, contains a large proportion of fat, which is extracted and used for various commercial purposes, such as the manufacture of fine soaps and candles and frequently as a substitute for butter. Cocoanut oil and resin melted together yield a substance capable of being used with success in filling up the seams of boats and ships, and in tropical countries for covering the corks of bottles as a protection against the depredations of the white ant. A quart of the oil may be obtained from six to ten nuts. The hard shell is easily polished and lends itself to the formation of various utensils and ornaments. It also has a high fuel value.

Although considerable is known of the constituents of the cocoanut, of its nutritive value and commercial uses, little has been done to ascertain the nature of the changes which the nut undergoes during germination. At the suggestion of Dr. MacDougal we have undertaken such a study, more especially from the chemical standpoint, and although our work in this particular connection has not been quite as fruitful as we had hoped it might be, our results are not without some interest.

II. CHEMICAL COMPOSITION OF THE UNGERMINATED COCOANUT

Before beginning our work on the germinating seed we felt it desirable to make ourselves thoroughly familiar with the chemical qualities of the ungerminated nut. This seemed all the more desirable because of the incomplete as well as the disconnected chemical data thus far recorded in this connection. This purpose was accomplished in a large number of analyses of numerous samples. We record the more important of these results, with comparative data from the work of others, on the following pages.

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* United States Dispensatory, 1619. 1899.

† American Journal of the Medical Sciences, 67 : 281. 1889.

Most of the nuts subjected to the analyses referred to farther on were furnished to us for this work by Hon. Wm. Fawcett and the United Fruit Co., who sent them in their husks from Jamaica. They were ripe, fresh and of about the average size. A few determinations were made with material from nuts bought in the markets in this city—source unknown, though doubtless of West Indian origin. These were of ordinary size, appeared to be ripe and fresh, and gave essentially the same analytic results as those obtained directly from Jamaica.*

We wish at the outset of this paper to thank Dr. MacDougal not only for the supply of material with which he favored us, but also for the suggestions which led us to undertake this work and for the kind encouragement he has given us from the beginning.

PROPORTIONS OF MILK, ENDOSPERM AND SHELL IN THE HUSKED NUT.—The weights and proportions of the main parts of the nut without its husk were carefully ascertained in special observations, as well as incidentally in other experiments.† The milk was removed as indicated on page 328. The empty nut was quickly broken with a hammer, the endosperm and germ, with the thin seed coat, carefully and promptly removed with a knife, and the fresh moist parts weighed at once. The results given on the opposite page were obtained in this connection.‡

The only results recorded on these gross relationships that we have been able to find were those obtained in a single experiment by v. Ollech, and those by Bachofeu.§ The parts of a single cocoanut, except the milk, were dried in the air by v. Ollech.||

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* A few showed signs of deterioration, such as "popping" on opening, free acid in the milk, etc. These were, of course, discarded.

† The weight of the fibrous husk varies considerably, as the amount of moisture increases by absorption or decreases by evaporation. The weights of the other parts are ordinarily not subject to such fluctuations.

‡ The weights of the germ and the thin seed coat enveloping the endosperm were included with the latter.

§ See also Berzelius: Lehrbuch der Chemie. Translated by Wöhler, 7: 533. 1838.

|| v. Ollech: Quoted by König, Die menschlichen Nahrungs- und Genussmittel, etc., 2: 495. 1893.

FRESHLY IMPORTED NUTS (FROM JAMAICA).

Number.	Weights in Grams.				Percentage of total Weight of husked Nut.			Milk.	
	Fruit without Husk.	Shell.	Endosperm with Germ and Integument.	Milk.	Shell.	Endosperm with Germ and Integument.	Milk.	Vol. c.c.	Specific Gravity.
1	845	255	437	153	30.2	51.7	18.1	150	1018
2	771	198	379	194	25.7	49.2	25.1	190	1017
3	658	168	371	119	25.5	56.4	18.1	117	1020
4	718	199	351	168	27.7	48.9	23.4	164	1019
5	597	152	327	118	25.5	54.8	19.7	113	1022
6	463	127	251	85	27.4	54.2	18 4	83	1019
7	622	195	334	93	31.3	53.7	15.0	90	1023
8	563	144	329	90	25.6	58.4	16.0	87	1027
9	633	166	374	93	26.2	59.1	14.7	90	1027
10	530	156	282	92	29.4	53.2	17.4	90	1021
11	637	150	363	124	23.5	57.0	19.5	121	1024
12	497	144	267	86	29.0	53.7	17.3	85	1014
13	538	162	283	93	30.1	52.6	17.3	90	1021
14	413	123	256	34	29.8	62.0	8.2	33	1030
15	511	158	309	44	30.9	60.5	8.6	43	1037
16	578	190	320	68	32.8	55.4	11.8	67	1016
17	568	142	350	76	25.0	61.6	13.4	74	1026
18	495	140	293	62	28.3	59.2	12.5	60	1024
19	813	221	392	200	27.2	48.2	24.6	194	1021
20	758	208	393	157	27.4	51.9	20.7	150	1022
21	584	148	339	97	25 4	58.0	16 6	94	1028
Aver.	609	169	333	107	27.8	55.2	17.0	104	1023

NUTS FROM THE MARKET (NEW YORK CITY).

1	1070	250	558	262	23.4	52.2	24.4	254	1018
2	1009	251	506	252	24.9	50.1	25.0	246	1015
3	728	202	417	109	27.7	57.3	15.0	106	1027
4	800	226	450	124	28.2	56.3	15.5	120	1026
5	688	191	385	112	27.8	56.0	16.2	110	1015
6	565	131	316	118	23.2	56.0	20.8	116	1017
7	639	210	382	47	32.9	59.8	7.3	46	1024
8	638	210	311	117	32.9	48.8	18.3	115	1017
9.	480	125	304	51	26.0	63.3	10.7	48	1034
10	561	158	307	96	28.2	54.7	17.1	92	1024
11	733	204	414	115	27.8	56.5	15.7	110	1024
12	762	176	380	206	23.1	49.9	27.0	202	1020
Aver.	722	194	394	134	27.1	55.1.	17.8	130	1021

They represented the following proportions of the total weight, which was 1,133 grams:

Fibrous Husk.	Shell.	Endosperm with Germ.*	Milk.
30.45 per cent.	19.59 per cent.	37.78 per cent.	12.18 per cent.

Of the total weight of the husked nut, which, by calculation, must have been 788 grams, the percentages of the parts were (calculated by us):

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* Including, doubtless, the seed coat as well.

Shell.	Endosperm with Germ.	Milk.
28.17 per cent.	54.32 per cent.	17.51 per cent.

These results, it will be observed, harmonize closely with the averages of our own determinations.

The data obtained by Bachofeu in this connection will be found in the table on page 335.*

COMPOSITION OF THE MILK.—The milk was poured from the nut through an opening made in the "eye" of the fertile carpel (see page 350) with a cork-borer. Extraneous matter could easily be kept out of the milk by this procedure and, besides, the fluid could be obtained when desired in a perfectly fresh, unevaporated condition.

The milk was found to be faintly turbid and opalescent in each case, and always contained a few oil globules and occasionally crystalline matter. It was acid in reaction to litmus although, as shown by lacmoid, no free acid was present in the normal fluid. The reaction is due to acid phosphate. Both alkali and earthy phosphate are present. The latter can be precipitated, in part at least, on boiling. An abundant precipitate of phosphate is obtained when the milk is made alkaline. The average specific gravity, determined with the aid of a hydrometer, was, as already noted on page 327, 1,023 and 1,021. The average specific gravity of the mixed milk of 15 nuts not included in the table on that page was 1,023. Of eight additional nuts not referred to there, and examined at another time, the figures for the mixed milk were 1,022.

The milk reduces Fehling's and Nylander's solutions and it ferments. It contains some monosaccharide which, from the characters of the phenylosazone derivatives, appears to consist of either dextrose or galactose, probably of both. Disaccharide in the form of cane-sugar is also present in good quantity, as might be inferred from the sweet taste of the milk.

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* Results having some relation to these are given by Atwater: Report of the Storrs (Conn) Agricultural Experiment Station, 123. 1899. Hammerbacher (Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875) found that the endosperm of two nuts weighed 835.8 grams; the milk, 303.95 grams. See also, pages 331 and 356.

On standing the milk turns sour, becomes thicker, and has much the odor and physical appearance of soured cow's milk. The milk ferments readily. As it does so the acidity increases with a production of acid from the sugar. Alcohols are also produced in the process. The distillate from the fermented milk has an agreeable taste and an alcoholic odor.*

Chlorides are prominent with phosphates among the inorganic substances of the milk. It contains only a very small quantity of proteid, coagulating above 80° C., and also traces of a proteose-like body. Very faint biuret and xanthoproteic reactions were obtainable with the fresh fluid. A snow-white precipitate consisting in part of earthy phosphate is obtained on warming the milk on the water-bath at 70° C. The filtrate from this product when boiled yields a delicate turbidity of coagulated proteid which becomes flocculent on addition of a slight excess of acetic acid. The filtrate from this coagulum gives only a very faint biuret reaction. Cocoanut milk is said to contain malate of lime.†

GENERAL COMPOSITION OF THE MILK

No.	Milk Used.		Percentage of Fresh Milk.				Percentage of Solids.	
	Specific Gravity.	Grams.	Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
				Total.	Organic.	Inorganic.		
1–*a*	1019	28.815	95.52	4.48	3.98	0.50	88.84	11.16
b		27.280	95.43	4.57	4.05	0.52	88.60	11.40
2–*a*	1020	25.403	95.28	4.72	4.27	0.45	90.58	9.42
b		27.837	95.44	4.56	4.14	0.42	90.70	9.30
3–*a*	1022	30.382	94.73	5.27	4.78	0.49	90.57	9.43
b		28.528	94.62	5.38	4.90	0.48	91.02	8.98
4–*a*	1016	25.958	95.73	4.27	3.88	0.39	90.81	9.19
b		25.823	95.65	4.35	3.96	0.39	90.92	9.08
c		26.298	95.68	4.32	3.91	0.41	90.57	9.43
5–*a*	1021	29.416	95.11	4.89	4.47	0.42	91.38	8.62
b		29.467	95.23	4.77	4.36	0.41	91.39	8.61
c		24.667	95.24	4.76	4.35	0.41	91.31	8.69
6–*a*	1024	23.119	95.44	4.56	3.82	0.74	83.68	16.32
b		23.886	95.33	4.67	3.92	0.75	84.04	15.96
7–*a*	1028	22 540	94.80	5 20	4.18	1.02	80.38	19.62
b		26.690	94.94	5.06	——	——	——	——
8–*a*	1027	28.722	95.02	4.98	4.21	0.77	84.45	15.55
b		28.409	94.97	5.03	4.26	0.77	84.69	15.31
Aver.	**1022**	**26.847**	**95.23**	**4.77**	**4.21**	**0.56**	**88.47**	**11.53**

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* Cocoa beer, containing 3.4 per cent. "Extractive," has been made by Calmette: Chemisches Centralblatt, **2**: 394. 1894.

† Harley and Harley: Proceedings of the Royal Society of London, **43**: 464. 1887–88.

On evaporation to a small volume on a water-bath the fresh milk becomes darker in color, takes on an odor characteristic of sugar syrups and looks not unlike molasses. Cane-sugar crystallizes from it in abundance on cooling.

The analytic data given on page 329 were obtained in our study of the general composition of the perfectly fresh milk of the Jamaican nuts.[*]

Percentage results in this connection had been obtained previously as follows:

Water.	Solids.	Organic Matter.	Inorganic Matter.	Nitrogenous Substance.	Fat.	Nitrogen-free Extractives	Carbohydrates.
91.50[†]	8.50	7.31	1.19	0.46	0.07	6.78	—
91.37[‡]	8.63	7.50	1.13	0.38	0.11	—	7.01[§]

These results were obtained with milk from nuts grown in the eastern hemisphere. The milk from the Jamaican nuts appears, as we have seen, to contain less solid matter, both organic and inorganic. This difference is emphasized by Hammerbacher's[¶] observations on the specific gravity of cocoa-milk. He describes the milk as a colorless, slightly opalescent fluid with a specific gravity at 20° C. of 1044.[**] The milk from two nuts weighed 303.95 grams. From the nitrogen-free extractive substance in 77.8 grams of milk contained in a third nut, 0.8504 gram of dextrose was obtained. When milk was warmed with dilute sulphuric acid an odor of volatile fatty acid became perceptible. A crystalline barium salt was prepared from the distillate of the acidified milk which was found to consist of barium propionate.

The milk contains a small amount of diastatic ferment and also oxidase.[††] We were unable to detect any other enzymes.

The following results were obtained by van Slyke[‡‡] in his comparative studies of the milk of six *unripe* nuts and of one ripe one:

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[*] The methods of analysis used for this and similar purposes, throughout our work, were those commonly employed in the laboratory. See Vandegrift and Gies: American Journal of Physiology, 5: 287. 1901.

[†] Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875.

[‡] König: Menschlichen Nahrungs- und Genussmittel, etc., 2: 308. 1893. See also Bizio: Pharmaceutisches Centralblatt, 756. 1833.

[§] Including 4.42 per cent of cane-sugar. See page 328.

[¶] Hammerbacher, *loc. cit.*

[**] See our large number of determinations of specific gravity on page 327. Also references on pages 328 and 329.

[††] Hunger: Journal of the Society of Chemical Industry, 20: 1030. 1901.

[‡‡] Van Slyke: Chemisches Centralblatt, 1: 595. 1891. Compare with results on page 329.

Constituents.	Milk of unripe Nuts.							Milk of ripe Nut.
	1	2	3	4	5	6	Average 1–6.	
Weight in grams. . .	230.5	378.6	347.0	383.7	350.0	330.0	336.6	109.6
Specific gravity . . .	1,024.6	1,023.0	1,022.3	1,023.0	1,022.1	1,021.5	1,022.8	1,044.0
Water (per cent.)	94.37	94.48	94.59	94.89	95.27	96.43	95.01	91.23
Total solid matter (%)	5.63	5.52	5.41	5.11	4.73	3.57	4.99	8.77
Inorganic substance.	0.575	0.635	0.675	0.611	0.658	0.602	0.626	1.06
Glucose	4.58	3.83	3.45	4.06	4.36	3.56	3.97	Trace.
Cane-sugar. . .	Trace	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	4.42
"Albuminoid" . .	0.120	0.126	0.114	0.205	0.140	0.095	0.133	0.291
Fat . .	0.084	0.100	0.138	0.131	0.145	0.120	0.120	0.145

The chief chemical differences induced by growth, as indicated by the above results, are an increase in the proportion of solid matter, including ash, fat and nitrogenous substance. Glucose almost entirely disappears from the milk of the ripe nut, cane-sugar replacing it—a fact evidencing synthetic production of disaccharide from monosaccharide.

Hammerbacher, believing that the endosperm develops directly from the milk, determined the quantitative relationships of the saline matters contained in each part from the same nut. He gives the following as his percentage results :

	Ash of the Milk.	Ash of the Endosperm.*
Potassium,	55.200	43.882
Sodium,	0.728	8.392
Calcium,	3.679	4.628
Magnesium,	6.606	9.438
Chlorine,	10.373	13.419
Phosphoric acid,	20.510	16.992
Sulphuric acid,	5.235	5.091
Silicic acid,	——	0.500
	102.331	102.342
Minus oxygen for chlorine,	2.338	3.024
	99.993	99.318

The above results indicate a particular increase of the content of sodium chloride in the ash of the developing endosperm and a corresponding decrease of potassium phosphate. See pages 322 and 335. The amount of silicic acid in the endosperm is also noteworthy. See page 335.

ENDOSPERM. *General Composition.*—The pure white kernel or "meat" of the nut is fibrous in structure, closely lines the shell, is from 1 to 2 cm. thick, and contains a very large proportion of fat. It is the part used most frequently for dietetic purposes. It possesses a characteristic and pleasant odor and is very agreeable to the taste. The endosperm cells do not contain starch granules, but fat needles and proteid lumps are present in them. The proteid particles are partly crystalline.*

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* Compare with results of Bachofeu's analysis, given on page 335. Our own results were the same as these qualitatively. See also Schaedler Technologie der Fette und Oele des Pflanzen- und Thierreichs, 840, 1892, who found 3.60 per cent. of iron in the ash of the endosperm in addition to the above constituents.

After the kernel has been finely divided in a meat chopper, the resultant hash may be subjected to increasing pressure, when an oily juice is obtained from it. The filtrate from this turbid mixture has a higher specific gravity than the milk of the nut, is acid in reaction, reduces Fehling's solution, contains a dextrin-like body and the milk salts, gives the proteid color reactions, yields coagulable proteid, and on dilution with water becomes turbid from precipitated globulin.

General Composition of the Endosperm

No.	Endosperm used.	Percentage of fresh Endosperm.				Percentage of Solids.	
	Grams.	Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
			Total.	Organic.	Inorganic.		
1-*a*	8.467	47.70	52.30	51.19	1.11	97.88	2.12
b	9.728	42.10	57.90	56.79	1.11	98.09	1.91
c	10.900	46.60	53.40	52.34	1.06	98.01	1.99
2-*a*	11.885	48.31	51.69	50.65	1.04	98.01	1.99
b	12.151	48.90	51.10	50.01	1.09	97.87	2.13
c	11.707	52.29	47.71	46.61	1.10	97.69	2.31
3-*a*	8.762	43.90	56.10	55.20	0.90	98.39	1.61
b	8.185	47.73	52.27	51.20	1.07	97.95	2.05
c	8.923	46.31	53.69	52.71	0.98	98.18	1.82
4-*a*	11.511	47.89	52 11	51.05	1.06	97.97	2.03
b	9.501	46.90	53.10	52.05	1.05	98.02	1.98
c	9.244	47.50	52.50	51.43	1.07	97.96	2.04
5-*a*	8.942	42.80	57.20	56.17	1.03	98.21	1.79
b	9.312	43.79	56.21	55.21	1.00	98.23	1.77
6-*a*	10.214	50.30	49.70	48.68	1.02	97.95	2.05
b	10 624	48.70	51.30	50.28	1.02	98.02	1.98
7-*a*	10.746	42.21	57.79	56.83	0.96	98.34	1.66
b	10.142	39.60	60.40	59.46	0.94	98.45	1.55
Aver.	**10.052**	**46.31**	**53.69**	**52.66**	**1.03**	**98.07**	**1.93**

The data given above were obtained for general composition of the endosperm immediately after the nuts were opened.†

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* See pages 342 and 352.

† The methods were the same as those employed with the milk. The thin seed-coat was trimmed off and the pieces of kernel cut into small, thin pieces with a knife. The material was taken from all parts of the nut.

Comparison of the averages given on the opposite page may be made with the following previously recorded results for the fresh endosperm from nuts of eastern origin : [*]

	FRESH ENDOSPERM			DRY ENDOSPERM	
Water.	Total Solids.	Organic Matter.	Inorganic Matter.	Organic Matter.	Inorganic Matter.
46.64	53.36	52.39	0.97	98.20	1.80

The agreement is seen to be very close.

By reason of the dietetic and commercial values of the various constituents of the endosperm of the cocoa fruit, numerous products of the kernel have been made and analyzed. The air-dried endosperm, or so-called " copra," is shipped in large quantities from the tropics. Cocoa-oil is obtained from the copra by various methods in countries distant from the tropics, the solid residues remaining after extraction serving various purposes. This residue makes up the so-called " cocoa-cake " obtained in the process of expressing the oil at various degrees of temperature. It is also ground into " cocoa-meal." In both forms, the residual substance

Products Analyzed.	Water.	Total Solids.	Organic Matter.				In-organic Matter.
			Nitrogenous Substance.	Fat.	N-free Extractive.	Crude Fiber.	
Air-dried endosperm or copra.[†]	5.81	94.19	8.88	67.00	12.44	4.06	1.81
Endosperm, perfectly dried.[‡]	——	100.00	10.29	67.35	15.11	5.42	1.83
Endosperm, free from fat and water.[‡]	——	100.00	31.49	——	46.25	16.69	5.57
" Cocoa-cake." [§]	10.30	89.70	19.70	11.00	38.70	14.40	5.90
" Cocoa-meal." [‖]	11.12	88.88	17.94	10.88	35.34	17.40	7.32
" Cocoa-meal," after extraction of oil. [¶]	4.55	95.45	23.20	1.85	64.45		5 95

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[*] Hammerbacher : Landwirtschaftlichen Versuchs-Stationen, etc., **18** : 472. 1875. See also Bizio : Pharmaceutisches Centralblatt, 757. 1833.

[†] König : Menschlichen Nahrungs- und Genussmittel, etc., **2** : 652. 1893. Also p. 308.

[‡] Hammerbacher : Landwirtschaftlichen Versuchs-Stationen, etc., **18** : 472. 1875.

[§] Dietrich und König : Zusammensetzung und Verdaulichkeit der Futtermittel, **2** : 1031. 1891.

[‖] Dietrich und König : *ibid.*, **1** : 725.

[¶] Schaedler : Technologie der Fette und Oele des Pflanzen- und Thierreichs, 624. 1892. (*a*) For references to digestibility and nutritive value of cocoa-cake see results of experiments on pigs and sheep given by Dietrich and König, **2** : 1031, 1036, 1040, 1123. (*b*) Compare above results with the table for general composition on the opposite page.

is used as food for cattle and as a fertilizer, having special value in both these connections.* It is sometimes also used illicitly as a food adulterant.

The analytic percentage results on page 333 have been reported by various agricultural chemists for such products from nuts grown in the eastern hemisphere.

The following summary of facts connected particularly with food value was given several years ago by Woods and Merrill: †

	Refuse.	Water.	Proteid.	Fat.	Total carbohydrates.	Ash.	Fuel value per pound; calories.
Edible portion,	——	14.1	5.7	50.6	27.9	1.7	2,986
As purchased,	48.8	7.2	2.9	25.9	14.3	.9	1,529
Without milk, as purchased,	37.3	8.9	3.6	31.7	17.5	1.0	1,872
Cocoanut milk, as purchased,	——	92.7	.4	1.5	4.6	.8	97
Shredded cocoanut,	——	4.3	6.5	63.7	24.1	1.4	
Shredded cocoanut,	——	2.8	6.0	51.0	39.0	1.2	
Edible portion,	——	5.8	8.9	67.0	16.5	1.8	
Cocoanut milk,	——	91.5	.5	.1	6.8	1.2	

Through the kindness of Dr. MacDougal we have been able to examine an account of "The cocoanut and plant vitality" in the Bulletin of the Botanical Department of Trinidad (July, 1900, p. 249). Reference is therein made to the report of Bachofeu in the Queensland Agricultural Journal for April, 1900. Bachofeu says: "Though there exist several analyses of parts of the cocoanut, no one seems to have undertaken the task of getting a complete analysis made with the view of ascertaining the actual demand made by the cocoanut upon the mineral constituents of the soil."

The results obtained by Bachofeu for a single nut are so complete, and so general in their interest and application that we quote, on page 335, his general summary in its entirety. ‡

Bachofeu's results indicate that sodium chloride and potassium phosphate are the chief inorganic matters drawn upon in the development of the cocoanut—chemical data in harmony with the fact that the cocoa palm does not thrive away from the coast or where salt is lacking in the soil. See second table, page 331.

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* v. Knieriem: Chemisches Centralblatt, 2: 672. 1898.

† Woods and Merrill: Bulletin, Maine Agricultural Experiment Station, No. 54; 81. 1899.

‡ The analyses were made in Ceylon. Native nuts were used.

BACHOFEU'S ANALYSIS OF THE COCOANUT

	Husk.	Shell.	Kernel.	Milk.
Total weight in lbs.	2.702	0.546	0.875	0.593
" " in per cent.	57.28	11.59	18.54	12.58
* { Moisture in per cent.	65.56	15.20	52.80	——
{ Dry matter in per cent.	34.44	84.80	47.20	——
Pure ash in per cent., containing viz :	1.63	0.29	0.79	0.38
Silica, SiO_2.	8.22	4.64	1.31	2.95
Oxide of iron and alumina, $Fe_2O_3Al_2O_3$.	0.54	1.39	0.59	Trace.
Lime, CaO.	4.14	6.26	3.10	7.43
Magnesia, MgO.	2.19	1.32	1.98	3.97
† Potash, K_2O.	30.71	45.01	45.84	8.62
Soda, Na_2O.	3.19	15.42	——	——
† Potassium chloride, KCl.	——	——	13.04	41.09
Sodium chloride, NaCl.	45.95	15.56	5.01	26.32
Phosphoric acid, P_2O_5.	1.92	4.64	20.33	5.68
Sulphuric acid, SO_3.	3.13	5.75	8.79	3.94
	100.00	99.99	99.99	100.00
† Containing total potash, K_2O.	30.71	45.01	54.05	34.54
* Containing nitrogen, N.	0.137	0.100	0.504	——

Thus of the more important ingredients of the soil 1,000 nuts remove the following :

In Lbs.	Husk.	Shell.	Kernel.	Milk.	Total Lbs.
Nitrogen, N.	3.7017	0.5460	4.4100	——	8.6577
Phosphoric acid, P_2O_5.	0.8456	0.0735	1.4053	0.1279	2.4523
Potash, K_2O.	13.5255	0.7127	3.7362	0.7783	18.7527
Lime, CaO.	1.8234	0.0991	0.2143	0.1674	2.3042
Sodium chloride, NaCl.	20.2375	0.2464	0.3563	0.5431	21.4233

Fat.—The striking chemical characteristic of the endosperm is its large content of oil. This may readily be extracted with fluids like ether. It can also be obtained in large proportion by pressure, particularly at the tropical temperatures. The fat has the consistence of butter in northern countries and possesses, when fresh, a fragrant and characteristic odor and an agreeable taste. It is snow white, sometimes cream-colored and readily crystallizes in large rosettes from the molten condition or from its alcohol or ethereal solutions. These crystals closely resemble those of palmitic acid. They melt at about 20–23° C., and congeal again several degrees below the melting point. They are fairly soluble in cold alcohol. Although cocoa-fat differs somewhat in composition in different countries, it has been found that the variations are comparatively slight. The temperature at which the oil is expressed influences these variations by increasing or decreasing the proportion of fats melting only at higher temperatures. These facts account for the variations in the figures given for melting point. Its specific gravity is 0.9+.

On heating to about 170° C., the oil gives off the odor of lactic acid; at a temperature of 300° C. acrolein may be detected. On long-continued heating with nitric acid the following dibasic acids are formed: succinic, adipic, pimelic, suberic and azelaic. Nitrocaproic acid is also formed.[*] The oil is very soluble in all of the well-known fat solvents. It contains some free fatty acid, but consists chiefly of glycerides of caprylic, lauric, myristic and palmitic acids.[†] Glycerides of caproic and capric acids are present in appreciable quantity; also a trace of stearin and some olein.[‡] The fat dissolves readily at a comparatively low temperature in an equal quantity of glacial acetic acid. Such a solution becomes turbid at 40° C.[§] By reason of its content of lower fatty acid radicles cocoa-oil has a high saponification value. Cocoa-oil is particularly resistent to the hydrating effect of superheated steam.[||]

The following data were obtained for the percentage fat-content in the fresh endosperm. The method of determination used was Dormeyer's:[¶]

	1	2	3	4	5	6	7	Gen'l Average.
Fresh endosperm, *a*.	38.27	40.01	36.71	35.10	34.60	38.90	38.60	
b.	36.14	40.54	35.02	34.90	34.10	40.70	38.40	
Average,	37.20	40.28	35.87	35.00	34.35	39.80	38.50	37.29

The ether extracts containing the oil were free from lecithin and could be almost entirely saponified. Hammerbacher * in the saponification of 25 grams of the pure oil obtained the following results:

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[*] Schaedler: Technologie der Fette und Oele des Pflanzen- und Thierrichs, 843. 1892.

[†] The presence of palmitin (tri) is doubted by Ulzer: Chemisches Centralblatt, II: 1143. 1899.

[‡] The so-called "cocinic acid" or "cocostearic acid" derivable from "cocin" or "cocinin" is, like the latter, a mixture. The former is a mixture of some of the above fatty acids; the latter of their glycerides. See Oudemans: Chemisches Centralblatt, 192. 1861.

[§] Valenta. Quoted by Vaubel: Physikalischen und chemischen Methoden quantitativen Bestimmung organischer Verbindungen, 1: 162. 1902.

[||] Klimont: Journal of the Society of Chemical Industry, **21**: 126. 1902.

[¶] Dormeyer: Jahresbericht über die Fortschritte der Thier-Chemie, **26**: 42. 1896. The fresh tissue was finely divided and weighed, then dried to constant weight at 100–105° C., and all of it extracted with anhydrous sulphuric ether. The usual amounts of tissue were used.

	Grams.	Per Cent.
Fatty acids convertible into *insoluble* lead salts,	15.1488	60.595
Fatty acids convertible into *soluble* lead salts,	9.5282	38.113
Glycerin,	0.5596	2.238
Total,	25.2366	100.946

The excess in weight of products is explained by the addition of hydroxyl groups in the cleavage of the triglycerides. König had previously found the glycerin content of cocoa-fat to be 2.08 per cent. Hammerbacher therefore concludes: "It follows from these results that this vegetable fat consists in greatest part of *free* fatty acid."

That there is some error in this conclusion, however, is evident from the results of later work. Benedikt † reports the glycerin content of cocoa-oil to be 13.3–14.5 per cent. Crossley and Le Suer found that the content of *free* fatty acid in terms of oleic acid varied between 2.50 and 8.86 per cent.‡

Stellwaag ‖ studied the fat extracted from cocoa cakes. This oil was rancid, of course. He found the quantity of *free* fatty acid to be only 9.84 per cent. The fat from the ether extract melted at 23° C. The saponification figure was 244.4. The extract contained 81.14 per cent. of neutral fat. The amount of unsaponifiable matter was 0.51 per cent. The molecular weight of the fatty acids was given as 207.¶

Studied through the oleo refractometer of Amagat and Jean, cocoa-oil is found to rotate to the left like an animal fat.**

The composition of cocoa-oil as determined by König †† is:

C.	H.	O.
74.15 per cent.	11.73 per cent.	14.12 per cent.

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* Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875.

† Benedikt und Zsigmondy: Chemiker Zeitung, 9: 975. 1885.

‡ Crossley and Le Suer. Quoted by Hopkins: Oil-Chemists' Handbook, 38, table iv. 1900.

‖ Stellwaag: Landwirtschaftlichen Versuchs-Stationen, etc., 37: 135. 1890.

¶ See also König, Menschlichen Nahrungs- und Genussmittel, etc., 2: 389. 1893.

** Blyth: Foods, Their Composition and Analysis, 359. 1896.

†† König: *loc. cit.*, 2: 385. See also, Brandes, Pharmaceutisches Centralblatt, 751. 1838.

The following facts regarding cocoa-oil have been compiled from various sources. They may be compared with similar data for other fats and oils given in the standard works of König, Staedeler, Lewkowitsch and others:

A. The heat of combustion of cocoa-oil is 9,066 small calories per gram.* It is as low as that of any other fat; slightly lower than butter. This is due to the fact that it contains a large proportion of fatty acids of low molecular weight.

B. Melting point is at 24° C. Congealing temperature is 22–23° C. Fatty acids from it melt at 24.6° C. They congeal at 19° C.†

C. Saponification value = 257.3–268.4‡

D. Iodine number = 9.0–9.5; same for its fatty acids = 8.5–9.0.§

E. Specific gravity = 0.9115 at 40° C.||

F. Acid value = 9.95–35.21.

G. Reichert-Meissl figure = 7.4; Hehner = 88.6–90.5.

H. Barium figure (König-Hart) = 117–120.

I. Molecular weight of the mixed fatty acids = 196–211.

The use of cocoa-fat and other cheap vegetable oils as a substitute for butter among the poorer classes has been increasing. Cocoa-fat is better adapted for cooking than for table use. It is frequently employed as an adulterant of ordinary butter. Prepared cocoa-fat makes a fairly good substitute for common butter. The fresh material becomes rancid after a time, because of its accumulating content of free fatty acid resulting from bacterial agency. Volatile acids are formed. Its tendency to rancidity is not as great, however, as that of animal fats. The fatty acid present in the fat to begin with can easily be removed with insoluble basic compounds, such as magnesia. By this means

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* Merrill. Quoted by Sherman and Snell: Journal of the American Chemical Society, 23: 166. 1901.

† König: Menschlichen Nahrungs- und Genussmittel, etc., 2: 322. 1893.

‡ König: *Ibid.*

§ Benedikt. Quoted by Vaubel: Physikalischen und chemischen Methoden quantitativen Bestimmung organischer Verbindungen, 2: 235. 1902.

|| Values given after E–I inclusive are quoted by Hopkins: Oil-Chemists' Handbook, 38, table iv. 1900. See also Lane: Journal of the Society of Chemical Industry, 20: 1083. 1901.

a "butter" is made from this oil which has the merit of enduring hot climates without becoming rancid. This product has been recommended for military and naval uses.*

Among the prominent commercial products is the cocoa-butter made in Mannheim, Germany.† König‡ found this product to have the following percentage composition :

Water.	Solids.	Organic Matter.	Inorganic Matter.	Fat.	Fatty Acid.	Nitrogenous Substance.
0.15	99.85	99.848	0.002	99.848	trace.	trace.

It has been stated that cocoa-butter is not very easily digested and that it does not agree with sick people.§ The recent researches of Bourot and Jean, ‖ however, show that a specially prepared cocoa-butter melting at 31° C. and containing only a trace of free fatty acid, is quite as easily and completely digested as ordinary butter.¶

We have already alluded to some of the commercial uses to which cocoa-fat is put. Soaps made from it combine with or hold an unusual amount of water while still retaining special hardness, one pound of the oil yielding three pounds of soap.** It is thus well adapted for the preparation of toilet soaps. The soaps made from cocoa-oil are characterized by great solubility in salt solution and can be precipitated from such fluid only by the addition of a very large excess of salt. The so-called "marine" or "salt water soap" has the property of dissolving as well in salt water as in fresh water and is made of cocoa-oil and soda.††

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* Rusby : Reference Handbook of the Medical Sciences, **3** : 164. 1901.

† See Leffman and Beam : Select Methods in Food Analysis, 182. 1901.

‡ König : Menschlichen Nahrungs- und Genussmittel, etc., **2** : 309. 1893. See also Schaedler, Technologie der Fette und Oele des Pflanzen- und Thierreichs, 1340. 1892.

§ Liebreich : Encyklopaedie der Therapie, **1** : 744. 1896.

‖ Bourot und Jean : Jahresbericht uber die Fortschritte der Their-Chemie, **26** : 58. 1896. See also v. Knieriem, Chemisches Centralblatt, **2** : 672. 1898.

¶ "Cocoanut cream," a dietary product much used in the tropics, is made by grating the endosperm and squeezing through cloth the fluid from the finely divided material. In a warm climate the resultant mixture contains much oil and is a very delicious accessory food. Besides the oil, the "cream" contains chiefly carbohydrate and proteid. See page 332 for references to similar fluid obtained from the endosperm by pressure in our own experiments.

** Ebermayer : Physiologische Chemie der Pflanzen, 344. 1882. See also Joss, Pharmaceutisches Centralblatt, 449. 1834.

†† See Schaedler, Technologie der Fette und Oele des Pflanzen- und Therreichs, 1178–1188, 1892, where may be found the results for percentage composition of the sodium soap, given at the bottom of the next page :

The harder fats of the oil make excellent candles. They are used also as constituents for suppositories and related therapeutic products. Medicinally the oil is employed repeatedly as a substitute for lard, olive oil and cod-liver oil. It is also made the chief substance by bulk in various salves and in cold cream, pomade and similar cosmetic preparations. In ointments and cerates it is especially valuable because of its ready absorption when rubbed on the surface of the body ; further, it takes up an unusual amount of water—a useful quality when it is desired to apply saline solutions externally. It shows little tendency to produce chemical changes in substances with which it may be associated.

Crude Fiber and Carbohydrates.—Cellulose is a prominent constituent of the endosperm. Associated with the fibrous elements is a polysaccharide, present in comparatively large quantity. This substance is only slightly soluble in water, is insoluble in alcohol, but readily soluble in salt solution. It is precipitated along with globulin when saline extracts of the kernel are dialyzed (page 341). The gum is readily transformed into sugar by the action of diastase or ptyalin.

The fluid pressed from the finely divided endosperm contains a slight amount of reducing sugar—dextrose. Galactose appears to have been identified also.* Cane-sugar is also present.

The following results were obtained in our determinations of the percentage content of crude fiber in the fresh tissue : †

	1	2	3	4	5	General Average.
Fresh endosperm, *a*	3.96	3.20	2.98	3.40	2.78	
b	4.21	3.80	3.12	3.52	2.98	
Average,	4.08	3.50	3.05	3.46	2.88	3.39

Proteids.—That the meat of the cocoanut contains at most only a very small amount of proteid matter is seen at a glance from the following percentage results for content of nitrogen.‡

Water.	Fatty Acid.	Sodium Oxide (combined).	Sodium Oxide (free).	Other Salts.	Residue.
58.74	32.82	4.26	1.50	2.26	0.42

See also the Dispensatory of the United States of America, 1899 : 1619, for references to objectionable chemical qualities of some cocoa-soaps.

* Green : Soluble Ferments and Fermentation, 100. 1899.

† Determinations were made, after the fresh weighed material had been dried and thoroughly extracted with ether, by the method adopted by the Association of Official Agricultural Chemists : Bulletin, Division of Chemistry, U. S. Department of Agriculture, 46 : 26.

‡ In these determinations the Kjeldahl method was employed.

	1	2	3	4	5	6	7	General Average.
Fresh endosperm, *a*	0.657	0.734	0.806	0.738	0.766	0.776	0.701	
b					0.740	0.781	0.756	
Average,	0.657	0.734	0.806	0.738	0.753	0.778	0.729	0.742

The fresh endosperm contains an average of 0.74 per cent. of nitrogen which, multiplied by the usual factor, 6.25, would indicate 4.63 per cent. of "albuminoid." Some of this nitrogen, however, is undoubtedly closely associated with the fibrous elements. Much of it probably is in the form of nitrogenous extractive.* Some of the nitrogenous substance is soluble in 95 per cent. alcohol.

The proteid present in the endosperm appears to consist chiefly if not exclusively of globulin and proteose (globulose ?), the globulin predominating in quantity.† We have made several samples of cocoa globulin by the method used by Osborne for the preparation of edestin—in general as follows : ‡ The kernel was run through a hashing machine and the finely minced substance freed from fat by repeated extraction in ether for several days. The ether adherent to the tissue was evaporated at room temperature and the ether-free tissue then extracted in 10-per-cent. salt solution for 24–48 hours. The saline extract was then filtered off and globulin thrown from its solution either by the dilution process, by dialyzing for several days in running water, or by treatment with ammonium sulphate to complete or half-saturation. The deposit of globulin resulting thereby always contained an appreciable amount of gummy carbohydrate. The carbohydrate admixture was eliminated by subjecting the deposit to the action of diastase or ptyalin for 24–48 hours, in the presence of thymol at 45° C. in neutral fluid, during which time it was transformed into soluble reducing sugar.§ The globulin residue left behind after this treatment was further purified by re-solution and re-precipitation. For quantitative analysis some of the final product was washed in water, alcohol and ether, and dried at 100°–105° C. to constant weight.

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* The factor 6.25 is here too large, also, because the proteids present contain about 18 per cent. of nitrogen. See pages 343 and 344. Stutzer found that, of the total nitrogen of cocoa-cakes, from 1.8 to 6.9 per cent. was contained in non-proteid substance. Quoted by Dietrich and König : Zusammensetzung und Verdaulichkeit der Futtermittel ; 2 : 987, 1380. 1891.

† The amount of nucleoproteid must be very slight.

‡ Osborne : See various papers in the Journal of the American Chemical Society since 1894.

§ Similar difficulty was experienced by Osborne, who got rid of the gum by repeated dialysis and precipitation with ammonium sulphate. Journal of the American Chemical Society, 17 : 429, 539. 1895.

Sometimes the globulin prepared in this way was both crystalline and amorphous. At other times it was entirely crystalline. Triangular, hexagonal and rhombohedral forms were frequently seen, although octahedra predominated.* The crystals so closely resemble those we have repeatedly made from hempseed and linseed by the same method, and are so like those given by Osborne for edestin,† that we felt satisfied from the beginning our globulin would prove to be of the edestin type. Careful study of the reactions of the substance convinced us of this fact, for it gives all of those attributed to edestin by Osborne.

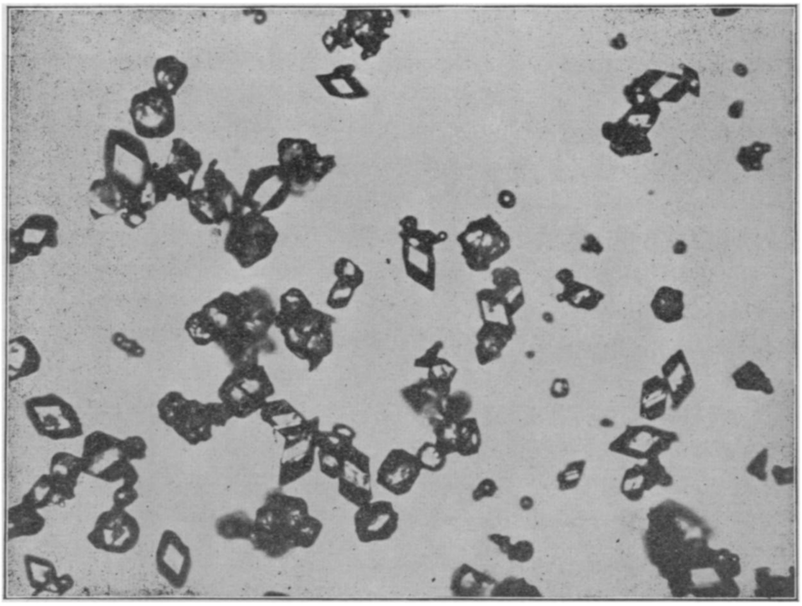

FIG. 4. Crystals of cocoa edestin.

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* The large proportion of gum extracted by the saline solution made it difficult not only to prepare the proteid in pure form but to obtain it quantitatively. Besides, the edestin passed in part into an insoluble modification during the manipulations. An appreciable loss resulted, therefore, in each preparation. We obtained as much as 25 grams of the purified product from the kernels of twelve nuts.

† Osborne: Journal of the American Chemical Society. See also his paper on crystalline vegetable proteids in the American Chemical Journal, 14 : 28. 1893.

On the opposite page we give a microphotographic view of edestin crystals from our second preparation Although not the purest, we have selected this preparation for this purpose because its crystals are mostly rhombohedra. These forms rarely occur in abundance in edestin precipitates, octahedra being more commonly obtained. Most of the larger masses among the crystals shown here are "rounded" octahedra; not in perfect focus because they are thicker than the rhombohedra. The smaller particles consist of globular matter and crystal pieces.

The crystals given in *Fig. 4* were photographed for us by the writer's colleague, Dr. Edward Leaming, who cordially gave us the benefit of his large experience. We wish here again to extend to Dr. Leaming our sincere thanks for his valuable assistance.

That the substance under discussion is edestin is further shown by the results of analysis. We append our results for nitrogen content, as determined by the Kjeldahl method, calculated for ash-free substance:

PERCENTAGE OF NITROGEN IN COCOA EDESTIN

Preparation.	1	2	3	4	5
Analytic results.	17.87 17.77 17.79	17.85 17.96 17.91	17.66 17.69 17.78	18.14 18.21 18.18	18.23 18.20 18.28
Average.	17.81	17.91	17.71	18.18	18.24
Ash.	0.41	0.13	1.12	1.90	1.84

Preparations 1, 2 and 3 contained amorphous material, possibly some of the gummy matter referred to on page 342, in spite of our efforts to completely remove it. Preparations 4 and 5 were obtained from 1 and 3 by further treatment with diastase and by recrystallization by dialysis from 10-per-cent. salt solution. They were practically wholly crystalline.

The above results show that the globulin separated from the cocoanut by the methods here employed is edestin.*

This same proteid of the cocoanut was examined by Ritthausen, † who termed it conglutin without really identifying it with that substance. His analyses gave it a content of nitrogen of 17.87–17.91 per cent. Chittenden and Setchell ‡ referred to it by the name of phytovitellin. The composition they gave for it is in general accord with that of edestin (nitrogen content = 18.40 per cent.), and as they obtained it partly crystallized in octahedra, Osborne* has lately suggested that the substance is edestin. The results we have obtained confirm Osborne's deduction.

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* The edestin from barley contains 18.10 per cent. N. That from maize 18.12 per cent.; from rye, 18.19 per cent.; wheat, 18.39 per cent. Osborne: Journal of the American Chemical Society, 17: 547. 1895.

† Ritthausen: Jahresbericht über die Fortschritte der Thier-Chemie, 10: 18. 1880.

‡ Chittenden and Setchell: Quoted by Chittenden, Digestive Proteolysis, 32. 1895.

The proteose to which we have already alluded was obtained from the globulin filtrate. The latter was freed from traces of globulin by the coagulation method, the hot filtrate evaporated to a small bulk on the water-bath and the proteose precipitated and purified by the usual method.† About four grams were obtainable from fifteen nuts. The product contained both proto and deutero forms. Some heteroproteose was also detected in the products formed on dialysis and a trace of dysprotose was obtained.

The following results for nitrogen content in the ash-free substance were obtained by the Kjeldahl method:

PERCENTAGE OF NITROGEN IN COCOA PROTEOSE

Preparation.	1	2	3	General Average.
Analytic results.	18.67 18.50 18.58	18.48 18.46 18.40	18.57 18.61 18.54	
Average.	18.58	18.45	18.57	18.53
Ash.	1.71	1.08	1.21	1.33

These results differ only slightly from those reported by Chittenden and Setchell.‡ This difference may be explained by the fact that mixtures of proteoses have been analyzed in each case by Chittenden and Setchell, and by us. Their preparation of proteose contained 18.25 per cent. of nitrogen.

In his volume entitled Digestive Proteolysis, Chittenden gives the analytic results for eleven different proteids and the proteoses derived from them (page 67). For seven of these the nitrogen of the corresponding proteose is somewhat higher than that of the original proteid. Analysis of our own preparations has shown the percentage of nitrogen to be greater in the proteose than in the globulin, a result in accord with the majority rule just noted.

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*Osborne: Journal of the American Chemical Society, **18**: 13. 1896.

† MacDougal: Practical Text-book of Plant Physiology, 164. 1901.

‡ Chittenden and Setchell: Quoted by Chittenden, Digestive Proteolysis, 32. 1895.

There appeared to be only a very slight amount of an albumin in our extracts—a coagulable substance which was not precipitated from its neutral solution when the latter was half-saturated with ammonium sulphate.*

Osborne's methods of extracting glutenin and gliadin † in dilute alkali and acid, and in dilute alcohol, after the removal of globulin, proteose and albumin as above described, gave mere traces of proteid substances in solution, derivatives, doubtless, of the proteids already referred to, which perhaps had not been completely removed from the residual tissue ; or possible nucleoproteid.

Peptone could not be detected in any of our extracts.‡

Ash.—Composition is referred to on pages 331 and 335. Qualitatively our results were the same as those there given.

Enzymes.—Water, salt solution and glycerin each failed to extract appreciable quantities of either proteolytic or adipolytic enzymes from the endosperm of the fresh, ungerminated nut, although an active amylolytic ferment was extracted by all of these fluids. The large quantities of fat and fatty acid in the endosperm suggest that an emulsifying ferment may be present. This, however, may be localized in the germ, increasing to physiological quantity and activity only in the process of germination (see page 358). The proteoses present in the endosperm seem to imply the presence of a proteolytic ferment. Possibly, however, the proteoses represent a residue from which the globulin was derived by reverse process.§

We have already referred to the fact that oxidase has been detected in the milk. Traces of it are also contained in the endosperm.

Average Composition.—The average results of our analyses of the endosperm are summarized in the following table, which presents the data obtained for the composition of the fresh tissue and the dry solid matter derived from it (constant weight at 100–105° C.).

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* Cohnheim : Chemie der Eiweisskörper, 150. 1900.

† Osborne and Campbell : American Chemical Journal, 15 : 392. 1893.

‡ Small quantities of non-proteid nitrogenous substances were detected by Ritthausen : Chemisches Centralblatt, 230. 1880. Compare, also, with recent results respecting proteoses obtained by Bokorny : Chemisches Centralblatt, 1 : 1167. 1902.

§ See recent papers in the Zeitschrift für physiologische Chemie by Schulze and Kutscher and their associates.

PERCENTAGE COMPOSITION OF THE ENDOSPERM

Constituents.	Fresh Endosperm.	Dry Endosperm.*
Water.	46.31	
Solids.	53.69	
Inorganic matter.	1.03	1.93
Organic matter.	52.66	98.07
Fat (substance soluble in ether).	37.29	69.45
Crude fiber (cellulose).	3.39	6.31
Proteid (N × 5.5)†	4.08	7.60
Soluble carbohydrate, non-nitrogenous substance, extractive, etc. (by difference).	7.90	14.71
Nitrogen.	0.742	1.382

The previous results obtained by Hammerbacher‡ for the fresh endosperm from nuts of eastern origin were as follows:

Water.	Solids.	Inorganic Matter.	Organic Matter.	Fat.	Crude Fiber.	Proteid.	Non-nitrogenous Extractive.
46.64	53.36	0.97	52.39	35.93	2.91	5.49	8.06

COMPOSITION OF SHELL AND HUSK.—We have already alluded to some of the uses to which the shell and husk of the cocoanut are put by reason of the chemical and physical qualities they possess. Some facts regarding their chemical composition were given in the table on page 335.

The following percentage results of elementary analysis of the powdered shell were obtained by Baumhauer;§ all samples having finally been thoroughly extracted in alcohol and ether, and then dried at 120°–150° C.:

	Cocos nucifera.				*Cocos lapidea.*	
	1. Extracted in boiling water.	2. Extracted in boiling water, dilute alkali and acetic acid.	3. Extracted in boiling water, concentrated alkali and acetic acid.	4. Extracted in alkali and in chlorine water.	5. Same treatment as 1.	6. Same treatment as 4.
C.	52.99	47.19	46.27	43.72	52.20	44.20
H.	5.88	6.09	5.81	6.11	5.80	6.24
Ash.	1.43	——	1.00	——	0.22	0.55

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* According to Dietrich and König (König, Menschlichen Nahrungs- und Genussmittel, etc., 1: 612. 1893) the *air-dried* substance contains the following in percentage of the total dry weight:

Total Substance Soluble in Water.	Proteids Soluble in Water.	Sugar (Sugar-Yielding Substance).
15.16	2.27	9.25

† The factor 5.5 is used because the proteids of the endosperm contain 18 per cent. of nitrogen. See references in this connection on page 341, footnote.

‡ Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875.

§ Baumhauer: Pharmaceutisches Centralblatt, 601. 1844.

Nitrogen was detected in small amount in the powders which had not been treated with alkali. The alkaline extracts contained substance, precipitable by acetic acid, with the following percentage composition: From *Cocos nucifera*, C = 50.04, H = 5.81, ash = 4.45 ; from *Cocos lapidea*, C = 52.15, H = 5.93, Ash = 1.00.

Tromp de Haas and Tollens * were able to show the presence of a large amount of pentosane (xylan) in the endocarp, the powdered material yielding an abundance of xylose on hydration in 4 per cent. sulphuric acid. Mannose was absent from the acid solution from which the xylose had been crystallized. After xylan had been completely removed from the shell-powder by the above method, dextrose was derived from the residue on treatment with sulphuric acid in the usual manner.

In his very complete histological studies of the cocoanut, Winton † recently called attention to the fact that both the husk and shell contain a brown substance which is quickly changed to a reddish color by caustic potash, but is unaffected by alcohol, ether or any of the specific reagents for proteids, fats or resins. He also states that no immediate effect is produced by ferric chloride solution, but on long standing the color is changed to olive green. Winton has pointed out the presence of minute silicious bodies among the fibers of the husk.

Winton, Ogden and Mitchell ‡ give the following percentage data for the composition of the shell :

Water,	7.36	Alcohol extract,	1.12
Solids,	92.64	Reducing matters calculated as starch,	20.88
Organic matter,	99.46		
Inorganic matter,	0.54	Starch,	0.73
Soluble in water,	0.50	Crude fiber,	56.19
Insoluble in HCl,	0.00	Nitrogen,	0.18
Ether extract,	0.25	Albuminoid (N × 6 25),	1.13
Non-volatile,	0.25	Quercitannic acid,	1.82
Volatile,	0.00		

During germination the shell remains unaltered. The husk soon begins to decay. See page 351.

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* Tromp de Haas and Tollens : Chemisches Centralblatt, **2** : 359. 1895.

† Winton : American Journal of Science, IV. **12** : 265. 1901. Facts are also given regarding the use of powdered cocoa-shell and the husk as adulterants of ground spices.

‡ Winton, Ogden and Mitchell : Report of the Connecticut Agricultural Experiment Station, **2** : 210. 1898.

COCOANUT PEARLS.—Within the nut there is occasionally found a small stony substance of a bluish white color, a kind of vegetable bezoar, called in India *calappa*, which is eagerly purchased by the Chinese, who ascribe great virtues to it as a sort of amulet to preserve them from diseases. The cause of its formation in the nut is unknown.

According to Harley and Harley * these pearls, like those of molluscan origin, appear to consist almost entirely of calcium carbonate, with water and organic matter in smaller proportion. Riedel, quoted by Harley and Harley, states that in 1886, while in North Celebes, he found a pearl in the endosperm of the cocoanut. One such a pearl was pear-shaped in form and 28 mm. long.

We are greatly indebted to Dr. D. Morris, Imperial Commissioner of Agriculture for the West Indies, for the following very interesting quotation from a letter to Dr. MacDougal:

"More than two hundred years ago Rumph, an eminent botanist in the East, sent as a present to the Grand Duke of Tuscany a ring in which a cocoanut pearl had been set. Further, Rumph himself described cocoanut pearls in his great work with considerable minuteness and gave illustrations of two of them. One was perfectly round, the other was oval or egg-shaped. * * * Travelers in the Philippine Islands have heard of cocoanut pearls, but seldom or ever have seen them. The natives, it is said, keep "cocoanut stones" as charms against disease and evil spirits. The rajahs, we were told, highly prized them and wore them as precious stones. It was only a few years ago that real cocoanut pearls were at last brought to England. One is now at the Museum at the Royal Gardens at Kew, brought by Dr. Hickson. It is almost egg-shaped, perfectly white, and composed almost entirely of carbonate of lime. It has, in fact, a somewhat similar composition to the pearl of the oyster, and yet there is little doubt it is a purely vegetable product." †

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* Harley and Harley: Proceedings of the Royal Society of London, 43: 464. 1887-88.

† "Besides these cocoanut pearls," quoting further from Dr. Morris' letter to Dr. MacDougal, "Rumph describes what he calls 'Melate' pearls taken from the flowers of a Jasmine; and a 'Champake' pearl taken from the flower of a Michelia. If we had not already seen the pearl of the cocoanut it would have been impossible to believe that there were such things as Jasmine and Michelia pearls * * * Of their composition, mode of occurrence and true nature we have yet to learn." See the article by Harley and Harley referred to above.

See also, on the subject of cocoanut pearls, the Proceedings of the Boston Society of Natural History, 1861 and 1862; The Tropical Agriculturalist, 1887; Nature, 1887.

III. CHANGES IN THE COCOANUT DURING GERMINATION

The nuts for our studies of the changes occurring during germination were obtained fresh, fully developed and with their husks still on them, directly from Jamaica. Immediately after their arrival at the New York Botanical Garden they were imbedded in earth until they were nearly covered. The earth was kept saturated with water and a tropical temperature was maintained. These conditions closely approximated those attending normal germination.

MORPHOLOGICAL CHANGES.—Nearly four months elapsed before the shoots began to appear through the husks, the fibers of the husk having been pressed aside in their upward progress. At this stage the stem of the shoot was an inch or more in diameter at the "root-crown," sharply tapering toward the point of penetration at the surface of the husk. As the growth proceeded it seemed to gradually become more and more rapid, and by the end of a year the plants had attained the height of two or three feet, with a stem about an inch in diameter throughout most of its length. By this time the part of the husk under the earth had decayed considerally; it became softer and more porous, and several stout roots had developed through it and penetrated the soil to the depth of a foot or more.*

The appearance of the nuts and their plants at this period of their growth is shown in the cut on page 350. Unless otherwise stated, the chemical analyses reported farther on were made of the parts at this stage of their development.

It may not be amiss, in describing the morphological changes induced in the nut during the process of germination, to also briefly review, at the same time, the more important facts regarding structure of the nut as it exists in the ungerminated condition.

The entire fruit is, strictly speaking, intermediate between a nut and a drupe — a "drupaceous nut." The outer covering,

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* For facts regarding germination and cultivation see Bailey: Cyclopedia of American Horticulture, 1: 341–343. 1900. Also, Wittmack, L.: Die Keimung der Cocosnuss. Ber. d. deut. bot. Ges. 14: 145. 1896.

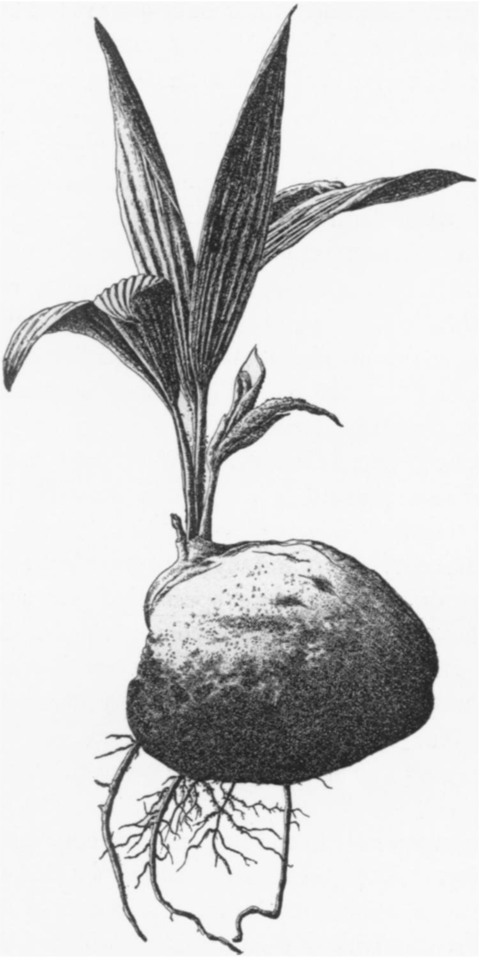

FIG. 5. Germinating cocoanut at the end of a year, showing plumule and roots, with husk little altered except where it was in contact with the earth.

usually removed before the nut appears upon the market, is a thick fibrous layer comprising the exocarp, the epicarp consisting of a smooth, thin, tough coat of a brownish or grayish color. (See pp. 323 and 324). The endocarp, or what is commonly known as the shell of the nut, is composed of three carpels whose lines of fusion are always apparent. The nut lies in the husk with the end containing the "eyes" toward the pedicel. Each carpel contains an "eye," so-called, and under one of these three eyes, the softest, is the germ imbedded in the endosperm. The fertile carpel may be recognized from the fact that it has the greatest degree of divergence between the longitudinal fusion lines of the carpels. The true integuments of the ovule are reduced to a thin brown coat closely adhering to the abundant endosperm.

The embryo is a cylindrical body about 8 mm. in length lying below one of the natural openings of the endocarp and in a line perpendicular to the exterior surface of the endosperm. When germination begins the embryo elongates and, having pushed through its thin coverings, begins to enlarge at both ends. From the outer end arises the plumule and the roots; the inner end is an extension of the true cotyledon and is developed into a special absorbing organ. See *pl. 19*.

The absorbing organ is of a soft spongy texture and all through it are the ramifications of vascular strands which converge to the narrow "neck," which connects the absorbing tissue with the stem. The cotyledon, and by this term, hereafter, we shall mean the part of that structure specialized for absorption, can attack only the part of the endosperm to which it is contiguous. In the earlier stages of growth this absorption is confined to the part nearest the young shoot, which we may hereafter refer to as the proximal end of the nut. Finally, however, the cotyledon fills the entire cavity of the nut and somewhat thins the endosperm distally, also.

The milk may persist in the nut until the cotyledon has almost filled the cavity. After germination has proceeded for some time the milk becomes insipid to the taste, and contains fragments of cellulose and large drops of floating fat. In nuts in which germination has continued for a year the cotyledon has entirely filled the cavity, but usually there is still left a third to a half of the endosperm undigested. This residual portion in normal cases is little affected, except that it is softened superficially, and to the taste suggests nothing different from the meat of the ordinary ungerminated nut.

In its natural development the roots of the plant soon take firm hold of the soil and, long before the endosperm is completely absorbed, junction between the shoot and the absorbing organ is broken, the husk decays and the plant enters an independent career. Neither the husk nor the shell appears to serve any other than passive mechanical function, and only the constituents of the endosperm and milk, so far as the nut is concerned, nourish the young plant before it finds in the soil the elements provided there in abundance for its growth to maturity.*

In our microscopic studies, particularly of the cotyledon, pieces of the fresh part were "fixed" in a mixture of glacial acetic acid (1/3) and 70% alcohol (2/3). After remaining in this fluid for a few hours the pieces were transferred to 70% alcohol and later to 85% alcohol, in which they were kept. Sections were cut with a razor and mounted in glycerin. Treated with iodine, such sections of the cotyledon showed an abundance of starch in all cells except those of the outermost layer or epidermis. This outer layer stained yellow with iodine. That it contained an abundance of oil was shown by its deep black reaction with osmic acid. Large globules of oil are, however, distinctly visible in the epidermis under the microscope without the aid of osmic acid. Oil may also be found in the subepidermal layers, but it rapidly diminishes in quantity as the distance from the outside increases and as the starchy deposit accumulates. Needle-like crystals may be very readily found in the epidermal cells. These resemble crystals of tripalmitin, but the fact that so much oil appears in globules, and that the breaking down of fats must occur to a large extent in these cells, would suggest that they are palmitic acid rather than the fat itself.

The above facts make it appear that the starch is formed indirectly at least from the oil.† See references under enzymes, pages 345 and 358.

See *pl. 19* for drawings of parts mentioned above.

CHEMICAL CHANGES.—The following summary gives briefly the effects of germination on the individual nuts examined:

I. *Not Analyzed.*—A. Development had proceeded for nearly six months. The plumule protruded six inches above the husk. Roots had developed through the husk—two were about a quarter of an inch in diameter. The stem was very thick at the "root-crown" ; sharply tapered to the point of surface penetration. The fibers about the stem were tightly pressed together. The neck of the absorbing organ was very woody and fibrous in character. Absorption of the endosperm at the proximal end was quite marked; distal portion undiminished. Milk cavity largely filled by the absorbing organ. A small space at the distal end remained, containing viscid white material full of large oil globules; quantity less than 10 c.c.—doubtless concentrated milk. It was strongly acid in reaction from acid phosphate, reduced Fehling's solution, gave only a faint biuret reaction and was free from starch. The inner surface of the endosperm in the distal portion was soft, having the consistency of lard.

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* Note references on page 357 to the functions of the husk in holding water and possibly furnishing nutrient matter in its decay.

† Ebermayer: Physiologische Chemie der Pflanzen, 347. 1882.

The weight of the whole shoot, minus the roots, in the fresh condition was 28.1 grams. Dry, the weight was 4.25 grams or 15.1 per cent. of the fresh substance, indicating a presence of 84.9 per cent. of water in the original plant.

B. This nut, although germinating for the same period of time, was not quite as far advanced as the previous one, having shoots that were just emerging from the husk. The stem was thicker, however. In most respects its internal condition was exactly the same as that of the first. The fluid in the distal cavity was less in quantity, not as turbid, contained less oil—otherwise was the same as that of the previous nut.

The weight of the entire plumule was 38.8 grams. Dried, it weighed 5.75 grams. Thus it contained 14.8 per cent. of solid matter and 85.2 per cent. of water.

II. *Analyzed.*—1. Growth continued for eight months. The cotyledon entirely filled the cavity. About half of the endosperm was absorbed; practically all of that proximally except a thin layer. The distal residue of endosperm appeared to be normal in taste and appearance except on the surface, where the soft layer previously referred to — one fourth the entire thickness — could again be seen. The outer surface of the cotyledon, that part in contact with the endosperm, was much corrugated; the whole organ, solid but spongy, sweet and agreeable to the taste, pyriform. In the tables on page 354 and 355 the results of our analyses for this nut are indicated by the numeral 1.

GENERAL COMPOSITION OF THE PARTS OF THE GERMINATED COCOANUT

Parts of the Nut and its Plant.	Percentage of fresh Tissue.				Percentage of Solids.	
	Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
		Total.	Organic.	Inorganic.		
I. *Cotyledon.*						
A. Central, vascular portion : *a*—1	89.10	10.90	99.14	0.86	92.07	7.93
" " " *b*—1	87.71	12.29	99.10	0.90	92.25	7.75
" " " *c*—2	91.62	8.38	99.00	1.00	88.10	11.90
" " " *d*—2	91.41	8.59	99.11	0.89	89.71	10.29
" " " *e*—3	88.99	11.01	99.20	0.80	92.77	7.23
Central, between center and surface : *f*—3	86.07	13.93	98.94	1.06	92.36	7.64
Average.	**89.15**	**10.85**	**99.08**	**0.92**	**91.21**	**8.79**
B. Outer, corrugated portion : *a*—1	84.95	15.05	98.69	1.31	91.30	8.70
" " " *b*—2	82.79	17.21	98.93	1.07	93.85	6.15
" " " *c*—3	80.83	19.17	98.26	1.74	90.93	9.07
Outer portion—neck : *d*—3	78.98	21.02	98.58	1.42	93.24	6.76
Average.	**81.89**	**18.11**	**98.62**	**1.38**	**92.33**	**7.67**
II. *Residual endosperm.*						
C. Proximal portions after much absorption : *a*—2	19.09	80.91	99.13	0.87	98.92	1.08
b—3	23.42	76.58	99.16	0.84	98.90	1.10
Average.	**21.25**	**78.75**	**99.15**	**0.85**	**98.91**	**1.09**
D. Medial portions : *a*—1	31.65	68.35	99.03	0.97	98.58	1.42
b—1	30.36	69.64	99.06	0.94	98.65	1.35
c—2	28.68	71.32	99.25	0.75	98.95	1.05
d—3	25.77	74.23	99.23	0.77	98.96	1.04
Average.	**29.12**	**70.88**	**99.14**	**0.86**	**98.78**	**1.22**
E. Distal, normal portion : *a*—3	**46.08**	**53.92**	**99.02**	**0.98**	**98.12**	**1.82**
III. *Stem of the plant.*						
F. Base, "root crown," with petioles at lowest parts : *a*—1	86.21	13.79	98.95	1.05	92.37	7.63
b—1	86.51	13.49	98.70	1.30	90.38	9.62
c—2	85.15	14.85	98.84	1.16	92.06	7.94
d—3	84.31	15.69	98.68	1.32	91.60	8.40
Average.	**85.55**	**14.45**	**98.79**	**1.21**	**91.60**	**8.40**
G. Parts above the base, with more petioles : *a*—2	82.47	17.53	98.80	1.20	93.20	6.08
b—3	79.87	20.13				
Average.	**81.17**	**18.83**				
IV. *Petioles.*						
H. Alone, or with young leaves : *a*—1	83.63	16.37	98.57	1.43	91.27	8.73
b—1	82.55	17.45	98.63	1.37	92.15	7.85
c—3	82.13	17.87	98.75	1.25	93.01	6.99
d—3	82.17	17.83	98.63	1.37	92.34	7.66
Average.	**82.62**	**17.38**	**98.65**	**1.35**	**92.19**	**7.81**

GENERAL COMPOSITION OF THE PARTS OF THE GERMINATED COCOANUT.—*Continued*

Parts of the Nut and its Plant.	Percentage of fresh Tissue.				Percentage of Solids.	
	Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
		Total.	Organic.	Inorganic.		
V. *Leaves.*						
I. Mature or nearly so : *a*—1	74.66	25.34	98.35	1.65	93.49	6.51
b—1	71.99	28.01	98.10	1.90	93.20	6.80
c—2	72.60	27.40	98.34	1.66	93.93	6.07
d—2	72.51	27.49	98.41	1.59	94.19	5.81
e—3	68.45	31.55	97.96	2.04	93.52	6.48
f—3	70.65	29.35	98.39	1.61	94.52	5.48
Average.	71.81	28.19	98.26	1.74	93.81	6.19
J. Very youngest : *a*—3	87.22	12.78	98.50	1.50	86.67	13.33
VI. *Roots.*						
K. Short, not developed outside of husk, with soft tips : *a*—1	87.08	12.92	98.46	1.54	88.09	11.91
b—2	89 89	10.11	98.67	1.33	86.89	13.11
c—2	86.41	13.59	98.43	1.57	88.44	11.56
d—3	87.46	12.54	98.83	1.17	90.70	9.30
Average.	87.71	12.29	98.60	1.40	88.53	11.47
L. Parts of longer roots, taken near the stem : *a* – 1	77.92	22.08	98.80	1.20	94.59	5.41
b—2	82.65	17.35	98.85	1.15	93.34	6.66
c—3	81.09	18.91	98.50	1.50	92.09	7.91
d—3	79.47	20.53	98.77	1.23	94.00	6.00
Average.	80.28	19.72	98.73	1.27	93.51	6.49
M. Parts of longer roots, taken outside the husk : *a*—1	81.70	18.30	97.94	2.06	88.76	11.24
b—1	84.64	15.36	98.47	1.53	90.05	9.95
c—2	82.79	17.21	98.40	1.60	90.74	9.26
Average.	83.04	16.96	98.27	1.73	89.85	10.15

2. This nut represented germination after ten months and was essentially like the preceding in all respects. The roots were thicker and a number of good sized ones had not yet proceeded through the husk. Their ends were soft and watery, rounded and blunt. Analyses of this nut are referred to in the tables on pages 354–355 by the numeral 2.

3. Essentially the same as No. 2, both in stage of development and conditions of parts, although the time of germination was about two months longer. Analyses of the parts of this nut are referred to in the tables on pages 354–355 by the numeral 3.

4. This nut had germinated for just about a year. The follow-

ing weights of the fresh parts were very carefully taken; the data for nitrogen were determined by the Kjeldahl method.*

	Weight in Grams.	Percentage of Total Weight.	Percentage of Nitrogen.
Cotyledon,	196	28.1	
Central part,			0.14
Cortical layer,			0.31
Endosperm,	155	22.2	
Distal portion,			0 65
Proximal portion,			0.93
Shell,	161	23.0	
Stem,	16	2.3	
Lower part,			0.70
"Root crown,"			0.53
Roots,	41	5.9	
Inside of husk,			0.27
Outside of husk,			0.54
Petioles and young leaves,	58	8.3	0.29
Petioles,			0.39
Old leaves and petioles,	71	10.2	0 45
TOTAL WEIGHT,	698		
Shell and contents,	512	73.4	
Whole plant,	186	26.6	
Cotyledon and endosperm,	351	50.3	

The tables on pages 354–355 give all our results for general composition of the parts of the germinated nut.† Numerous deductions may be drawn from these results, as to growth and metabolism.

The central part of the cotyledon, with its vascular network, contains more water and less solid matter than any other part of the germinated nut. The proportion of solid substance in it increases toward the corrugated epithelium, being greatest in the "neck," where the structure is fibrous and woody.

That the absorbing organ completely takes up the milk is very evident from the way it fills the cavity and from its own composition, but it is likewise apparent from our results that water is also with-drawn from the residual endosperm, this absorption being greatest at the proximal end of the nut, where absorption was begun in the first place, and least at the distal end, where it had hardly commenced. The roots also are seen to have absorbed considerable moisture.

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* The husk was not weighed because it was decayed underneath and water-logged. Nitrogen was not determined in the shell because its substance remains unaltered during germination.

† The methods of determination were the same as those used previously. The roots, outside of the husk, which had been in the wet soil, were hurriedly rinsed with water to remove inorganic matter, then wiped dry with a towel and at once cut into thin cross sections for analysis.

The lowest part of the stem contains almost as little solid matter and is nearly as watery as the cotyledon. The percentage of water in the stem diminishes as the distance away from the "root crown" increases. The watery condition of the lower part of the stem is increased, doubtless, by the fact that the surrounding husk is impregnated with water, thus favoring direct absorption by osmosis and at the same time preventing evaporation from the surface of the growing tissue.

The amount of solid matter in the petioles is also comparatively slight, little more than in the lower part of the stem. In the leaves the water is greatest in the youngest, as would be expected; least in the oldest — those most exposed to the air.

The roots at the tips are soft and watery, but the older they become the more solid matter they develop and the more woody material they accumulate.

In the distribution of the inorganic matter in the fresh parts it is noticeable that the proportion of saline substance increases with a decrease of water and *vice versa*, as in the cotyledon, in the residual endosperm and throughout the plumule. This condition is such as might be expected. The relation of the inorganic to the organic matter in each part, however, is variable. The substance of the cotyledon and the stem contains a greater proportion of salts than that of the endosperm and the leaves, the roots likewise holding a fairly large amount of saline matter. The substance of the endosperm contains least of all, from which fact it is quite clear that the inorganic matter of the plumule has been absorbed, not only by the cotyledon from the milk, but also by the roots from the fluid in the husk and the surrounding earth.

At the beginning of germination the inorganic matter and water of the milk are doubtless sufficient for the changes that occur, the organic matter coming chiefly from the endosperm. Some time before the cotyledon fills the milk cavity and completely absorbs the milk, the roots have begun to take water and inorganic matter from the fluid in the husk—possibly also organic substance from the disintegrating husk fibers—and thus they absorb new nourishment from a large supply. Growth of the plumule is consequently favored. The plumule soon reaches such a height and development as to enable it to make increasing contributions to the plant metabolism from the gaseous products the air affords. By this time the whole growth has become practically independent of the reserve material of the seed.

ENZYMES.—We made only a few preliminary studies of enzyme distribution. Extracts were made in water, dilute salt solution and glycerin. The indicators used in nearly all the experiments were prepared from the materials in the nut itself.

The extracts of the cotyledon were acid to litmus (phosphates), though, as indicated by lacmoid, they contained no free acid. Diastatic ferment was found to be distributed in abundance in all parts of the cotyledon. Oxidase was also present. Only the very slightest proteolytic action was manifested by the cotyledon extracts, even when they were obtained in particularly concentrated form. In some experiments the results were entirely negative, however. Cellulose-dissolving and fat-splitting enzymes were not detected in either the cotyledon or the residual endosperm, although we cannot be sure that in our few experiments they have not escaped us.* Germination progresses so slowly that possibly some of the enzymes are present in only very minute quantity at any one time—in such amount, perhaps, as to be undiscoverable by the methods commonly employed for ferment detection. We did not examine the parts of the plumule in this connection.

At this point, before we were able to come to any very definite conclusions as to the enzymes present and before we could determine the distribution of proteids, fats, carbohydrates, etc., in the parts of the plant, we were obliged to discontinue our work. The writer hopes to extend these experiments on the germinated cocoanut to a consideration of related problems of nutrition.

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* See our references to enzymes on page 345. Lipase seems to have been found in the germinating cocoanut by Lumia: Jahresbericht über die Fortschritte der Thier-Chemie, 28: 724. 1898.

Explanation of Plate 19

FIG. 1. An end view of the cocoanut, without its husk, showing the three carpels and the "eyes." The fertile carpel is the one included in the largest angle.

FIG. 2. A sectional view through the end of an ungerminated nut, with its husk removed, showing the form and location of the germ imbedded in the endosperm (under the micropyle). The shell is indicated by the heavy outline.

FIG. 3. Another sectional view similar to that of Fig. 2 showing development of the absorbing organ after germination had proceeded for a few weeks. The incipient stem and roots are to be seen. The cotyledon has enlarged within and without the shell.

FIG. 4. A longitudinal section through the whole nut somewhat to the side of the median line. It shows the nut imbedded in its fibrous husk and the conditions found after germination had gone on for about five months. The absorbing organ has filled about two thirds of the cavity of the nut but has absorbed comparatively little of the endosperm. The stem has proceeded upward through the husk, the roots downward through the husk into the soil. The leaves have been cut off above the husk. (See page 350 for appearance of full plumule.)

FIG. 5. A section through the layer of the cotyledon normally in contact with endosperm, showing the corrugated, villiform arrangement of the absorbing epithelium. This section having been treated with osmic acid shows the localization of the fat globules.

FIG. 6. A section through that part of the cotyledon given in Fig. 5. This section, treated with iodine, shows the localization of starch.

FIG. 7. A few cells from the absorbing epithelium of the cotyledon after enlargement. This figure shows the large clear oil globules and the darkly staining starch grains in the subepidermal cells. The crystals seen in most of the cells appear to consist of fatty acid, possibly palmitic.

FIG. 8. Enlarged starch granules from subepidermal cells.